# Imperial College London



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## The Net Zero Opportunity: **Composite Material Innovations Reinforcing UK Aviation**

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"Net zero is the economic opportunity of the 21<sup>st</sup> century"

"We must act decisively to seize the opportunities in a global race"

Independent Review of Net Zero, 2023

### What is the problem?

• Decarbonising aviation is a global challenge. The UK aerospace sector must act now to be a part of this radical change - this is essential to not only protect the environment, but also to protect the UK aerospace industry.

## What are the solutions?

- Net zero concepts for civilian aircraft require more mass efficient structures.
- Composite materials can provide this, but to fully extract the mass saving benefit, we must develop solutions which make them more resistant to damage.

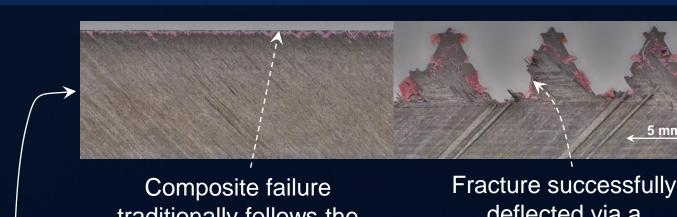
## Profiling concept for leading edge protection

#### Feature:

• Metallic erosion shields are used to protect composite leading edges on blades and wings

Vulnerability:

• The step change in stiffness at the edge of the erosion shield can accelerate failure in the composite part

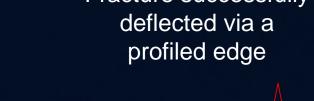


traditionally follows the metal's straight edge

0.16

0.14

0.12





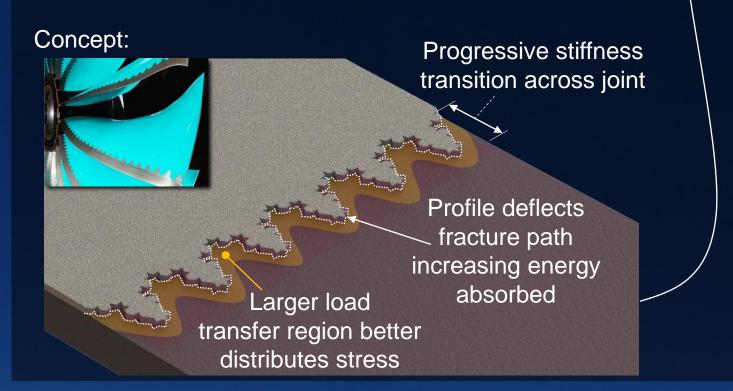
## 3D reinforcement for delamination resistance

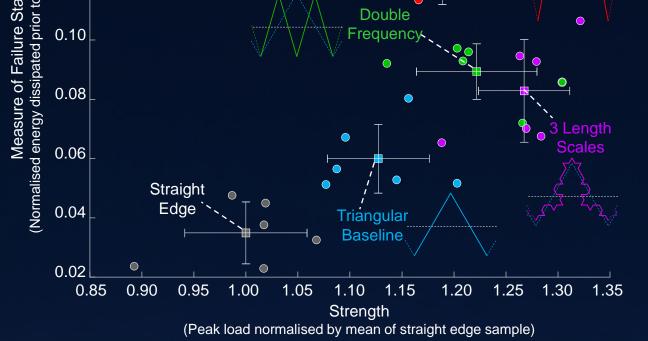
Feature:

• Composites are usually manufactured as 'laminates' – many layers of fibres pressed together with each layer comprising fibres of a single orientation

#### Vulnerability:

• These layers can separate (delamination), resulting in a rapid loss of stiffness and structural integrity





Profiled designs show increased strength and a more stable failure - results received recognition from SAMPE UK & Ireland

ZEROPARBUS

Manufacture of carbon

skin & stiffener in a single

Automated Fibre

Placement (AFP) process

AFP is being increasingly

adopted in industry – it

reduces material waste

and increases reliability

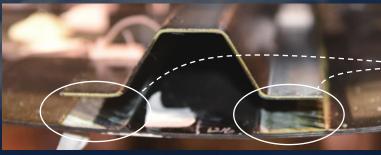
and rate of manufacturing

## **Bio-inspired embedded stiffener** for improved damage tolerance

#### Feature:

- Composite stiffened panels are composed of 'skins' with 'stiffeners' bonded to the surface
- They are used to provide structural stiffness in a mass efficient manner

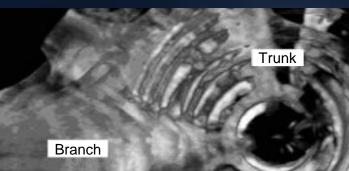
#### Vulnerability:

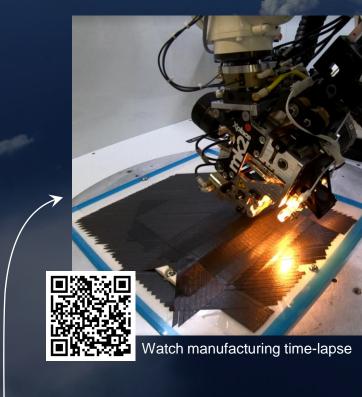


Stiffeners are vulnerable to separation failure!

This results in a sudden loss of structural integrity!

#### Concept:





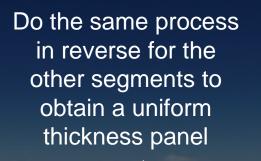
Traditional design

#### Concept:



Using tape-by-tape manufacturing, split plies into segments of alternating tapes

Repeatedly stack segments to create thickness variations





Cross-section micrographs



Through-thickness reinforcement is achieved which reduces spread of delamination damage

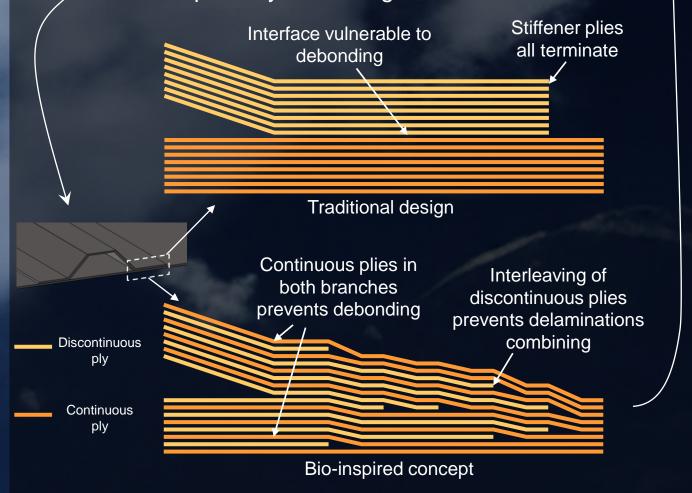
Bio-inspired design



🖽 Burns et al. 2012

Tree branches are embedded to the centre of the trunk creating a structure which is very damage tolerant

I designed a composite stiffened panel with the stiffener attachment embedded to the centre of the skin inspired by this biological structure



Unstable stiffener debonding

**Unstable failure!** From no detectable damage to immediate catastrophic failure

Bio-inspired design manufactured successfully via

AFP and is seen to prevent separation failure

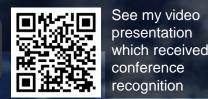
100







Crack grows progressively before ultimate failure - stable initial crack growth provides a warning allowing repair



## **Conclusions & future direction**

- We have developed innovative new concepts which demonstrate composite materials can be used to create damage resistant structures and by extension the aircraft of the future
- To capitalise on the net zero opportunity the demonstrated concepts must be applied at a higher TRL level with industry partners to realise our end goal of net zero aviation